



BER Improvement using BCH Coding and Interleaving in MIMO-OFDM

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General Note



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ABSTRACT

This review paper here deals with the concept of BCH coded and interleaved MIMO-OFDM (Multiple Input Multiple Output-Orthogonal Frequency Division Multiplexing), which improves the systems performance. The system shows a consistent improvement in BER performance. On adding BCH high performance Forward Error Correction (FEC) code on AWGN channel of OFDM with BPSK and QPSK technique, BER increases and also overcomes the major disadvantages like ISI (Inter Symbol Interference) and ICI (Inter Carrier Interference). AWGN have been used for analysis purpose and their effects on BER for high data rates have been presented. The proposed MIMO-OFDM system with BPSK using 2*2 antenna configurations has better performance in terms of BER Vs SNR as compared to QPSK.

Keywords: AWGN; BCH Code; BER; BPSK; FEC; Interleaving; MIMO-OFDM; QPSK ; SNR

1. INTRODUCTION

The combination of multiple input multiple output (MIMO) processing i.e. transmission takes place between multiple transmitting and receiving antennas along with orthogonal frequency division multiplexing (OFDM) is considered solution to wireless communication systems in recent years. MIMO OFDM systems have attracted great attention. MIMO-OFDM has become a practical alternative to single carrier and single input single output (SISO) transmission. Since SISO system is very simple and deals with communication between one transmitter and one receiver. The core MIMO OFDM property states that one data stream gets divided parallelly and each divided stream is transformed into frequency domain by OFDM technology (Figure 1). MIMO OFDM has succeeded in increasing the capacity and BER performance using forward error correction code (FEC) and interleaving. The FEC mechanism plays an important role in the performance of MIMO OFDM. The performance of MIMO-OFDM with a new set of BCH code is evaluated on AWGN channel. Additive white Gaussian Noise (AWGN) is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density and a Gaussian distribution of amplitude. ICI (Inter Carrier Interference) is a common problem found in high data rate communication. It occurs when transmission interferes with itself and the receiver cannot decode the transmission correctly. It is basically the distortion occurred due to interference with other sub carriers and the receivers cannot decode the transmission correctly. Guard interval is provided between the two symbols to avoid the ICI and it is exactly to the channel, thus data can be retrieved.

2. PROPOSED APPROACH CHANNELS

Here the study focuses on considering AWGN, Rayleigh and Rician channel for the implementation of our system.

1. AWGN Channel: AWGN is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density and a Gaussian distribution of amplitude.
2. Rayleigh Channel: In multipath environments, it is visualized that an impulse transmitted from the transmitter will reach the receiver as a train of pulses, and each path is modeled as circularly complexed Gaussian random variable. The model is called Rayleigh fading channel models.
3. Rician Channel: Rician channel is similar to Rayleigh fading except for the fact that there exists a strong line of sight component along with reflected waves.

BASIC INTERLEAVERS

1. General Block Interleaver: This interleaver rearranges the elements of its input vector without repeating or omitting any elements. If the input contains N elements, then the elements parameter is a column vector of length N.
2. Random Interleaver: The random interleaver rearranges the elements of input vector using a random permutation. This block accepts a column vector input signal [Design and implementation of a Multi-Mode Interleaver/Deinterleaver for MIMO OFDM Systems (Zhen-dong Zhang; Bin Wu, Yong-Xu Zhu; Yu-mei Zhou, 2009)] The number of elements parameters indicates how many numbers are in the input vector.
3. Convolutional Interleaver: This interleaver block permutes the symbols in the input signal. Internally, it uses a set of shift registers. The number of shift registers is the value of the rows of shift registers parameters. This interleaver accepts a scalar or column vector input signal, which can be real or complex. The output signal has the same sample time as the input signal.

ENCODING

1. BCH Encoder: BCH codes are t_c - random error correcting codes. The major advantage of these codes lie in the flexibility while choosing the code parameters like blocks length and code rate. The design considerations are to make the block size (n) smallest for a given message of k so as to obtain a desired value of d_{min} or for a given n and k, with largest d_{min} [Performance of Power efficient LDPC coded OFDM over AWGN channel (Mishra M; Patra; S. K; Turuk; A. K, 2012)]. The properties are discussed below:

For any integer $m \geq 3$, $t_c < (2^m - 1)/2$

Block length: $n = 2^m - 1$

Number of message bits: $k \geq n - mt_c$

Minimum distance: $d_{min} \geq 2t_c + 1$

2. Cyclic Encoder: The binary cyclic encoder creates a systematic cyclic code with message length k and code word length n. The number n must have the form $2^m - 1$, where m is an integer greater than or equal to 3 i.e. $m \geq 3$. The input must contain exactly k elements. If it is frame based, then it must be a column vector [Error Detection and Correction using the BCH Code (Hank Wallace, 2011)].

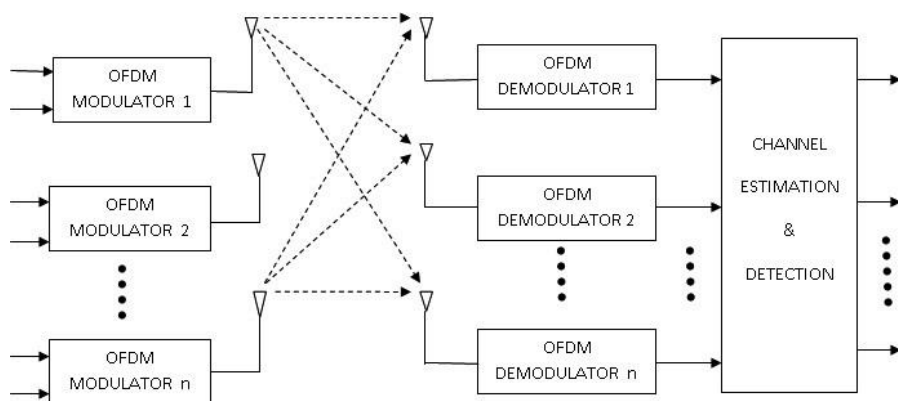


Figure 1

Block Diagram of MIMO System

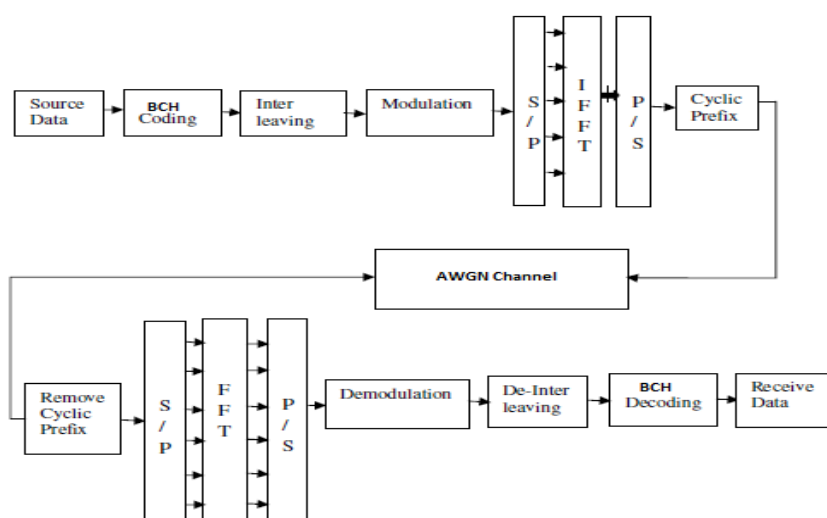


Figure 2

Block Diagram of OFDM System

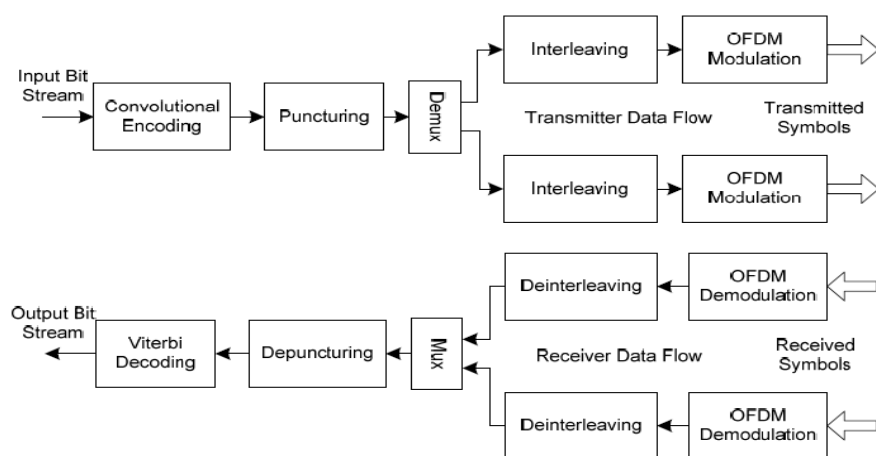


Figure 3

Cross Antenna Coding With Per Antenna Interleaving

3. Hamming Encoder: A hamming encoder is a block code capable of identifying and correcting any single-bit error occurring within the block, it is identified as an (n, k) Hamming code. Hamming codes employ modulo-2 arithmetic (Ex-OR), they have the following parameters.

Code length: $n \leq 2^{n-k} - 1$

Number of message bits:
 $k \leq n - \log_2(n + 1)$

3. SYSTEM DESCRIPTION

The basic ofdm system for this paper is shown in Figure 2. The data input bit stream is first encoded using BCH Code, a major FEC technique. In wireless communication, concept of parallel transmission of symbols is applied to achieve high throughput and better transmission quality. OFDM is one of the techniques for parallel transmission. The very first motive of OFDM is to split the total transmission bandwidth into a number of orthogonal subcarriers in order to transmit the symbols using the subcarriers in parallel. Cyclic prefix refers to the prefixing of a symbol with a repetition of the end, for it to be effective length of cyclic prefix must be at least equal to the length of the multipath channel [Wireless Communication (Upenadala, 2009)]. Basically Cyclic Prefix is added in OFDM in order to combat multipath by making channel estimation easy and the signal is transmitted.

At the receiver, reverse operation of the transmitter takes place i.e. the cyclic prefix gets removed, serial to parallel conversion, FFT, deinterleaving and finally parallel to serial conversion. OFDM signals are generated using Fast Fourier Transform. In OFDM, subcarriers overlap. Orthogonality between two signals means that the two coexisting signals are independent of each other in a specified time interval and do not interact with each other. They are orthogonal because the peak of one subcarrier occurs when other subcarriers are at zero. This can be achieved by realizing all subcarriers together using Inverse Fast Fourier Transform.

This paper analyses the bit error rate performance of BCH code in AWGN channel using BPSK and QPSK as the modulation scheme. The BCH encoder block creates a BCH code with constraint length $k=7$ and code word length n interleaved to leverage

frequency diversity. In the coding used above the input should contain exactly k elements and the output should be a vector for given codeword length n . Cyclic Extension helps in removing ISI effect on original OFDM. Using cyclic extension, symbol period is prolonged [Bit error rate analysis of OFDM/TDM with frequency domain equalization (H. Gacanin, S. Takaoka, F. Adachi, 2006; Digital Communication, J. G Proakis, 1985 and A MIMO-OFDM prototype for next generation wireless WAN'S, C. Dubuc, D. Storks, T. Geasy, and H. Yong, 2004). As correct no of samples are taken for decoding, they may be taken from anywhere within extended symbol. Since complete period is integrated orthogonality is maintained and ISI and ICI are eliminated. The work done by the channel is just that it adds a white Gaussian noise to the signal passing through it. Due to which fading does not exist.

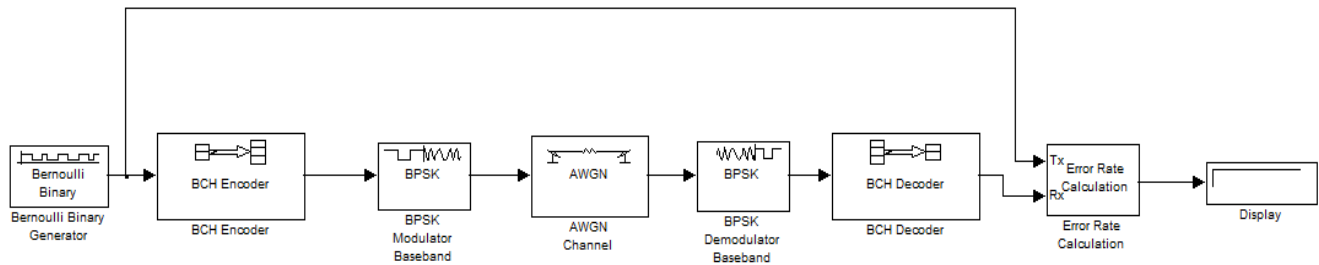


Figure 4

BPSK with BCH Code

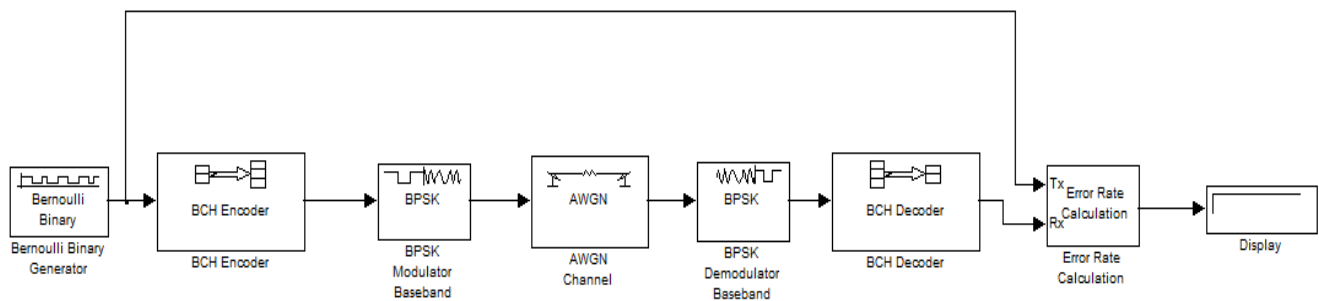


Figure 5

QPSK with BCH code

4. SIMULATION AND DISCUSSION

One aspect of MIMO-OFDM system that has adequately not investigated is the effect of using different combinations of encoders and interleavers for the systems performance. There are four possible schemes used by [Analysis and Design of Coding and Interleaving in a MIMO OFDM Communication System (Zafar Iqbal, 2012)], cross antenna coding with per antenna interleaving, per antenna coding with per antenna interleaving, cross antenna coding with cross antenna interleaving, and per antenna coding with cross antenna interleaving (Figure 3). Out of the four above mentioned possible schemes, the cross antenna coding with per antenna interleaving scheme has the best BER performance. The goal is to achieve minimum memory usage, fast interleaving and increased speed of the overall system while maintaining BER performance. The Forward Error Correction (FEC) block includes encoding, puncturing and interleaving [Error Detection and Correction using the BCH Code (Hank Wallace, 2011)]. In the above used schemes, the input data is first encoded using BCH encoder followed by puncturing. The next step involved is interleaving using a random interleaver. The receiver then performs the same functions in reverse order. As in [Comparative Analysis of Reed Solomon Codes and BCH Codes in the Presence of AWGN Channel (Arjun Puri; Sudesh Kumar, 2013)] the application of an interleaver is basically to ensure uniform BER, as the performance can vary to a great extent. The choice of interleaving ensures better BER fairness and

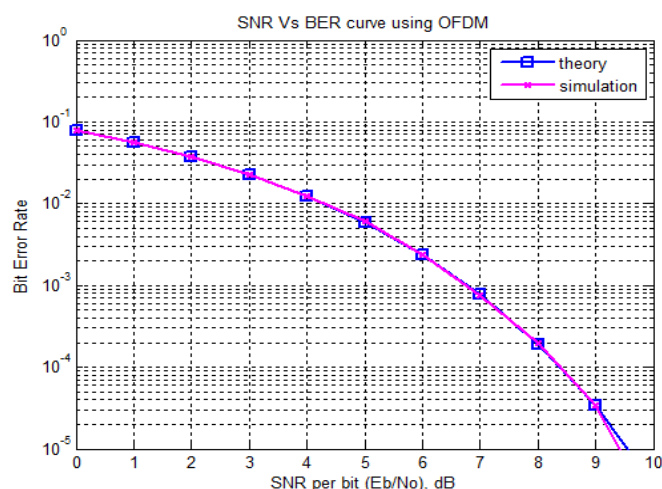


Figure 6

Basic BER Vs SNR curve

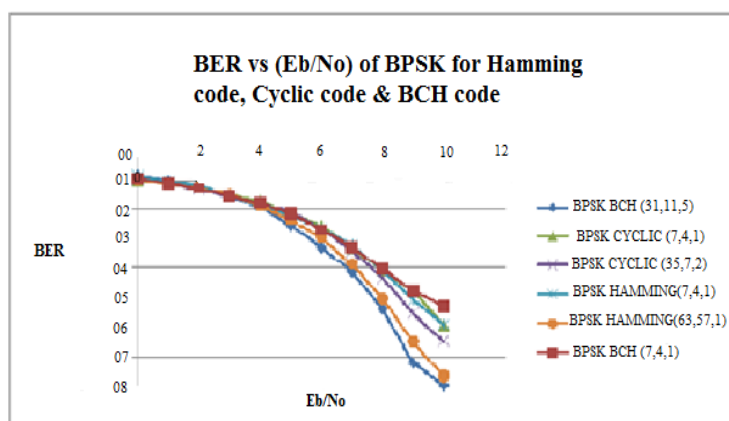


Figure 7

BPSK System

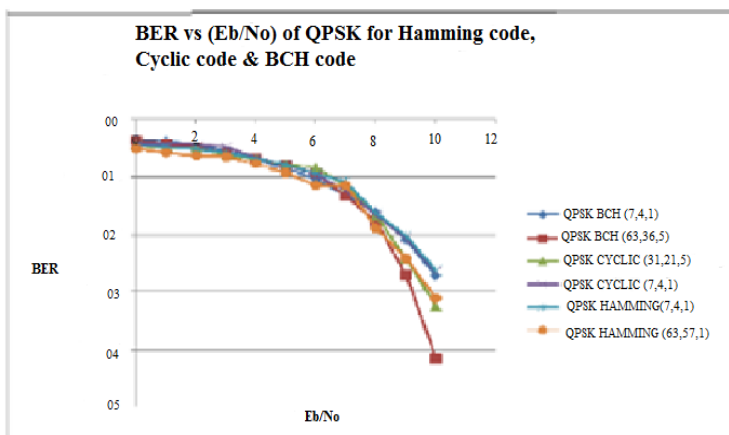


Figure 8

QPSK System

complexity of the system also get reduced. Resulting in minimizing the maximum SNR, hence random interleaver reduces it and achieves equivalent BER.

5. INTERLEAVING TECHNIQUE COMBINED WITH CODING

As in [Low Weight Distribution of Parallel Concatenated BCH Codes (Sina Vafi, 2010)] BCH code when implemented by the random interleaver has minimum weight and low multiplicity. It even obtained medium to high signal to noise ratio (SNR) to mitigate the errors. BCH code integrated with interleaving is mainly done to mitigate the effects of channel characteristic. Random errors can be corrected by channel coding techniques. Hence BCH code combined with interleaving is mainly done to mitigate the effects of channel characteristic.

INTERLEAVER

Interleaving has become extremely useful technique for minimization of errors. The basic work done by an interleaver is that it rearranges the order of symbols to be transmitted following a particular rule and at the receiver the reverse rule can be used to restore the original sequence.

The random interleaver here rearranges the elements of its input vector using a random permutation. The output signal inherits its data type from the input signal; the number of elements indicates the number of elements in the input vector. By using the same initial seed value in the random deinterleaver we can restore the permuted symbols to their original ordering. According to [Effects of Interleavers on BER fairness and Peak to Average Power Ratio in OFDM System (Sabbir Ahmed and Makoto Kawai, 2011)] random interleaver is constructed as a block interleaver and a random generator is used to generate the interleaver.

FORWARD ERROR CORRECTION (BCH CODE)

BCH code has a unique advantage that it has an ability to recover synchronization problem as the code is self synchronized [Interleave Division Multiple Access (L Ping, L. Liu, K. Wu and W. K. Leung, 2011)]. Its correction abilities are very powerful. BCH codes are better than the rest of the codes, because other codes are capable of detecting and correcting single errors only while BCH codes are capable of detecting and correcting multiple errors. Due

to this property, here BCH code has been chosen to study the bit error performance of BPSK and QPSK system (Figure 4 & 5). On considering the performance of communication system of BPSK and QPSK without and with error correcting codes using BCH code [New Codes from Dual BCH Codes with Applications in Low PAPR OFDM (Maryam Sabbaghian, 2011)], it is observed that the system with code has better performance than the system without codes so will produce a better performance [Comparative Analysis of Reed Solomon Codes and BCH Codes in the Presence of AWGN Channel (Arjun Puri, Sudesh Kumar, 2013)], [Error Control Coding:

Fundamentals and Applications (S. Lin and D. J Costello,2004)]. BCH coding even helps in improving the various problems that occur in the system while transmission and reception of data bit stream. There is a precise control over the number of symbol errors correctable by the code. As per the coding theory [Algebraic Coding Theory (Berlekamp, E.R, 1984)] BCH code can be designed by analyzing and choosing its generator polynomial. The BCH decoders are implemented using the well established techniques of BCH decoding. The number of errors for each codeword may be loaded into a shift register. A BCH (n, k, and t) code is capable of correcting a maximum of t symbols in an n symbol codeword, k is the code dimension (number of information bits by code word). The higher the value of n and k better is the performance. The best suitable channel that can be used is AWGN channel.

ADVANTAGE OF COMBINING FEC WITH OFDM

- The power to be transmitted can be reduced by using an error controlling scheme.
- With the reduction in the sizes of transmitter and received antennas the performance gets increased.
- There is a major improvement in BER and bandwidth efficiency.

6. RESULTS

The relationship between SNR and BER (Figure 6), with BPSK modulation is as follows:

$$BER = \frac{1}{2} \left[1 - \frac{1}{\sqrt{1 + SNR}} \right]$$

From Figure 7, results show that the best performance occurs when the communication system uses a BCH code with n=31, k=11 and t=5 with BPSK modulator /demodulator [A BCH Recovery Scheme for Adaptive Error in Wireless Networks (Houda Labiod)]. From Figure 8, results show that the best performance occurs when the communication system uses a BCH code with n=63, k=36 and t=5 with QPSK modulator/demodulator. In general, the BCH codes are better than hamming codes and cyclic codes. This is because hamming and cyclic codes are capable of detecting and correcting single errors only whereas BCH codes are capable of detecting and correcting multiple errors.

7. CONCLUSION

The main aim here is to find out the performance of BPSK and QPSK in AWGN channel with BCH coding and interleaving. There is a reliable performance of BER and bandwidth efficiency. The BCH FEC code is the best coding scheme to enhance the systems performance in BPSK using an interleaver which fulfils the demand of high data rate transmission.

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